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## BALANTIDIUM COLI INFECTION IN MAN.*

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THE infrequent occurrence of Balantidium coli in man has prompted the careful study of a fatal case, which occurred recently in the service of one of us (Dr. Bel), with a view of determining, if possible, the infectious nature of this infusorium. Interest in the case was stimulated by the fact that this is the first to be reported in an individual born in Louisiana who had never left the state, and the first to be carefully studied, both clinically and pathologically, in North America. We were fortunate to have seen the patient at an early stage of his complaint, and to have had the opportunity to follow, without interruption, the progress of the disease to its fatal termination. Moreover, as dysenteries are not uncommon in our semi-tropical southland, we are able to add another member, evidently endemic to this locality, to the already recognized bacillary and amebic types.

The significance of Balantidium coli in the intestine of man has been disputed by such workers as Malsmsten[1] and Doflein,[2] who hold to the harmless nature of the organism, and Strong,[3] Brooks,[4] Solowjew,[5] and others, who believe that the parasite is an important etiological factor in producing catarrhal and ulcerative lesions in the large intestine. From Strong's[3] and Solowjew's[5] studies in man, and the observations of Brooks[4] upon a fatal dysentery among the

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apes in the New York Zoological Garden, in which Balantidia were found, there is considerable evidence that these parasites are more than harmless commensals, and must be seriously considered as the cause of certain types of ulcerative colitis.

In perusing the literature on the subject, it is remarkable how little attention has been given to the lesions found in such cases—the authors seemingly devoting their studies to the biological features of the parasite, and the therapeutics, rather than attempting to solve the real pathogenic significance of the organism.

To Strong[3] and Solowjew[5] all credit is due, as the first to have carefully studied the lesions of the gut of fatal cases, and their interpretations and conclusions have thrown more light on the rôle played by these parasites than had been accomplished by recitals of clinical observations and therapeutical results. We have been greatly aided in our work by the excellent monographs of these authors.

While Strong[3] has been able to collect in the entire literature but 117 cases of balantidial invasion in man, of which but one is reported from the United States, we have personal communications from Dr. Mallory (Boston City Hospital) and Dr. Van Wart (Johns Hopkins Hospital) that a case had been encountered at each of these places in the routine study of autopsies, but, as these were incomplete, no attempt had been made to report them. Through the courtesy of Dr. Mallory, who sent us sections of the intestine from his case, we were able to compare the histological changes in it with those found in our case.

As invasions from this parasite have been reported from the cold climates of Finland and Russia, the temperate zones of North America, the tropical countries in South America, and the Philippine Islands, such wide geographical distribution precludes the possibility of associating infection by Balantidium coli solely with tropical or subtropical climates.

While the appearance of this infusorium in man suggests the possibility of its occurrence in other animals, it has as yet been found only in the intestine of swine, where it seems to be harbored without producing either marked clinical symptoms or pathological lesions.

Klein,[6] having found an organism which he believes to be Balantidium coli in sewage, and as the parasite has also been found in drinking water in London, suggests the possibility that infection may take place by this means. However, as 25 per cent of reported cases have occurred from direct contact with swine or following the ingestion of food products made from these beasts, little doubt exists as to the danger from this source. No better argument can be brought forward to confirm this belief than the instance related by Chichulin[7] in which an entire family had been infected after eating sausages made from a hog which harbored Balantidia. From the clinical history of our case, it appears very likely that infection was received through these animals.

## CLINICAL HISTORY.

The patient, a colored male, age 40 years, was born in Louisiana and had never left the state. He was admitted to the Charity Hospital, June 22, 1909, complaining of diarrhea, abdominal pain, and tenesmus. His family history was negative. He had had the usual diseases of childhood, and pneumonia and gonorrhea later in life. Had had a sore on his penis 20 years before admission. Indulged freely in tobacco and alcoholics.

A railroad hand by occupation, he was always provided good drinking water, but kept pigs at home and was often called on to attend them. In October, 1908, he began suffering from diarrhea. His bowels would move from 8 to 20 times a day, the stools often containing blood. This condition persisted for six weeks, after which the stools became normal and remained so for a week, when the diarrhea returned. From this time to the date of his admission he had periodical attacks of diarrhea, the intermission between them growing less and his general weakened condition becoming worse.

On admission he complained of abdominal pain and severe tenesmus and of having 20 to 24 bowel movements each day. The stools contained blood and mucus and their character suggested those of amebic dysentery. Repeated examinations of the feces failed to show the presence of ameba or other protozoal or bacterial invasion, excepting Balantidium coli, which were always found in large numbers and very active.

Blood smears were negative for protozoa, anemias and leukemias—the total counts showing an average of:

| | |
|---|---|
| Red blood cells | 4,570,000 |
| White blood cells | 4,200 |
| Hemoglobin | 85% |

The differential leukocytic count, taken at different times, averaged:

| | Percentage |
|---|---|
| Polyneutrophiles | 70 |
| Large lymphocytes | 2 |
| Small lymphocytes | 25.3 |
| Large mononuclear | 1.7 |
| Eosinophiles | 1.0 |

The examinations of the sputum and feces failed to show any acid-fast bacilli, altho the Morro cutaneous test gave a positive reaction.

The urine examinations were negative.

The temperature throughout his illness never exceeded 99° F. and was more often normal than otherwise. The pulse averaged 90, and the respiration 20 per minute. Blood pressure was 125 mm.

The physical condition of the patient was one of great emaciation—he reported having lost 70 pounds in weight during the 8 months previous to his admission. The skin was dry and the superficial lymph nodes of the neck, axillae, elbows, and groins were slightly enlarged. The pupils reacted normally to light and accommodation, and all other senses were normal.

Excepting a slight hebetude, the mental condition and nervous system generally were good.

The buccal mucous membrane showed a marked redness due to stomatitis, and the tongue was deeply furrowed and dry.

The thorax revealed pleuritic signs on the right side and the presence of many spots of consolidation in both lungs, which proved to be tuberculous. Shortly before death there were evidences of edema about the base of both lungs. The heart sounds were normal.

The abdomen showed marked retraction and a general absence of fat. There was tenderness on pressure, especially about the umbilicus and left inguinal region. The liver, spleen, and kidneys were negative, and, except for a scar upon the penis, nothing was noted abnormal about the genital organs.

The usual treatment for tropical dysenteries was administered, but, instead of improving, the patient gradually grew weaker and died, apparently from exhaustion, on September 7, 1909.

Briefly, were it not that Balantidium coli was found in the intestinal discharge, it would have been difficult to differentiate the intestinal upset in this case from that of an amebic infection—the intermittent diarrheal attacks, muco-bloody stools, tenesmus, and rapid emaciation of the patient were very suggestive of an amebic invasion.

AUTOPSY PROTOCOL: 2871. Dave Williams.

Body is that of a poorly nourished, but well-developed, black male. Body length 179 cm. Pupils equal and measure 6 mm. Sclerae yellowish-brown in color. There is a scar on glans penis. The superficial lymph nodes are not palpable. Cadaveric rigidity is absent. The body is warm. Necropsy held 2 hours after death. The abdomen is moderately distended and tympanitic. The intestines are greatly distended with gas. The small intestine is smooth and glistening; the large intestine is lusterless, opaque, and feels boggy and thickened, especially about the sigmoid flexure and rectum. There are no adhesions, except a few fibrous tags about the spleen.

Lungs.—Both are adherent at the apex to the thoracic wall by old fibrous tags. Few nodular masses are felt below the pleura and deeper into both organs. On section, these are found to be well circumscribed tubercles; many containing calcareous deposits. Besides these, there are bright red discrete areas scattered throughout both lungs. These areas are not elevated, but remain on an even plane with the remaining portion of the organ. They are very irregular, suggesting "ink blots." The lower lobes of both lungs are edematous. The bronchial glands are pigmented and enlarged, and the bronchi are negative.

Gastro-intestinal tract.—The stomach is contracted and its rugae are prominent.

It contains about 200 c.c. of a greenish turbid fluid. Examination of scrapings from its wall are found free of Balantidia. The small intestine contains much sticky mucus throughout its length, especially abundant about the lower portion of the ileum. The villi are prominent and deeply injected, especially those on the crests of the valvulae conniventes. No ulcerations or muco-purulent exudate can be found. Scrapings from the ileum, about 20 to 30 cm. from the ileocecal valve, show, on examination, a few living Balantidium coli. Similar scrapings from other portions of the ileum and jejunum are negative to Balantidia. The large intestine is swollen, thickened, and edematous throughout its length; more so at the curves, and especially so at the sigmoid flexure and rectum. The thickening does not appear to be due to an increase of connective tissue, but, rather, to edema. It seems to be confined to the mucosa and submucous coat. The mucosa is studded with shallow ulcers; their contents are muco-purulent and not adherent to underlying tissues. There is no diphtheritic membrane present. The ulcers are largest and most numerous in the sigmoid flexure and rectum and especially in the latter structure. There are also many smaller and more discrete ulcers at the different curves, probably for the same reasons that induce their presence at these points in other intestinal infections. The ulcers are not undermined nor heaped, but rather shallow with tapering edges. In general the gross appearance of the large gut does not suggest amebic dysentery. Examination of the exudate from the structure shows many living Balantidia. They are especially numerous where the lesions are the most marked at the angles of the gut and in the sigmoid and rectum.

Brain.—The ventricles are distended with a clear fluid. Two bright red clots, originating from the choroid plexus and adherent to it by a thin pedicle, extend forward into both lateral ventricles, and rest on the floor of the ventricles, without, however, being attached to their walls, but floating in the excess of contained fluid. On the velum are also noticed a few red points.

All other organs are normal.

Anatomical Diagonsis.—Chronic Pulmonary Tuberculosis (quiescent); Acute Ulcerative Colitis; Chronic Pleuritis; Intraventricular Hemorrhage (cerebral).

Aside from the slight lesions found in the lungs, there were no other evidences of tuberculosis to account for the marked cachetic condition of the patient; the rapid emaciation, intermittent dysentery, with tenesmus and bloody stools, suggested the picture of tropical dysentery. The failure to find ameba, both ante-mortem and at necropsy, eliminated the possibility of infection by these organisms, and the macroscopical appearance of the gut, with its small shallow ulcers, suggested a bacillary rather than a protozoal invasion. Its true nature was readily determined by the histological study.

## MICROSCOPIC ANATOMY.

With the exception of small petechial hemorrhages in various organs, and the pulmonary lesions, nothing is found on microscopic examination of sections from the lungs, heart, liver, spleen, kidney, pancreas, brain, or stomach, to suggest invasion by Balantidium coli. The mesenteric lymph nodes are enlarged, and there is a marked increase in their lymphoid cells. No Balantidium coli found.

The small intestine is normal, except about the lower portion of the ileum where a slight derangement of the epithelial cells, a moderate amount of mucus containing some polymorphonuclear leukocytes, and a marked injection of the blood vessels offer the only evidences of inflammation. Balantidia cannot be found, either in

the glands or in the exudate, altho they were present in scrapings of the ileum at autopsy.

The mucosa of the large intestine, aside from definite ulcers, is uniformly infiltrated with inflammatory cells. The ulcerated sites show an absence of glands and are filled with polymorphonuclear leukocytes, many lymphoid and plasma cells, and a moderate number of eosinophiles. There is little or no fibrin present. These ulcerated areas do not seem to extend much below the muscularis mucosa, the greater number appearing to be limited by it (Plate 3, Fig. 4). Some of the more recent ulcers are confined to a single Lieberkühn gland; the inflammatory process having followed downward from the orifice of such gland, the epithelial lining is lost for the most part. Capping the ulcers, and extending for a considerable distance over the edges, is a dense layer of polymorphonuclear leukocytes held in a delicate reticulum of fibrin. Balantidium coli is often found in large numbers in this exudate. The absence of acute inflammatory exudate in the submucosa is evidence that the superficial process is secondary. In those parts of the mucosa where ulcers are absent, the interglandular supporting tissue is densely infiltrated with lymphoid and plasma cells, the latter predominating. Altho a few eosinophiles are present, there is an absence of polymorphonuclear leukocytes. The small blood vessels in these locations are deeply injected, and some show a slight perivascular leukocytic zone. The conditions are responsible for the swollen appearance of the mucosa in the gross. The glands are, in places, greatly compressed, many showing complete obliteration of their lumen; in other parts they are dilated and cystic, and lined with a single layer of compressed epithelium (Plate 3, Fig. 4). These conditions of the glands have resulted from the interglandular cellular infiltration. Balantidia are found in the lumen of the glands (Plate 4, Fig. 1) and also superficially and deep into the interglandular supporting tissue (Plate 4, Figs. 2 and 3). The lesions in these areas may be regarded as subacute or chronic, and evidently incited by the presence of the organisms.

In the submucosa the connective tissue is pushed apart, the result of serous exudate (edema), and apparently by the burrowing of Balantidium coli through the tissues. The perivascular lymph spaces are filled with lymphoid and plasma cells; and similar cells are scattered throughout the submucosa. The blood vessels are deeply injected; especially is this marked in the region of the mucosal ulcers. There is no proliferation of their endothelial wall. Some of the vessels contain Balantidium coli (Plate 4, Figs. 4 and 6). The lymphatics are swollen but show no activity on the part of their endothelial lining. The solitary follicles show no apparent histological changes. Some of the nerve plexuses in the vicinity of the ulcers show a marked polymorphonuclear leukocytic invasion obliterating the plexuses almost entirely. There is an absence of phagocytic cells of any sort. The muscularis mucosae throughout some of its extent is disarranged, swollen, and edematous.

In attempting to interpret these findings, it was noticed that the small shallow ulcers were mostly limited to the mucosa, only a very few penetrating the muscularis mucosae, and none extending any distance into the submucous coat. From the exudate it was evident that the condition about these ulcers was mostly acute in

character, and that while Balantidium coli was found in the loose exudate that capped the ulcers, none was found in their walls where the lesions were active. On the other hand, at some distance from the ulcers, in the lumen of the glands, which were but little affected, in the thickened interglandular supporting tissue, and in the submucous coat, Balantidium coli was found in great numbers. As both the interglandular tissue and the submucosa were infiltrated with cells, characteristic of subacute or chronic inflammation, and as the parasites were present in, or very near to, these lesions, it can be inferred that they were responsible for its existence. The presence of the parasite in the blood vessels and lymph channels in the submucosa argues well for the possibility of carrying the infection to the liver or lung through these routes, and, while we could not find Balantidium coli in either organ, the hemorrhagic areas found in the lungs are so unusual and so suggestive as to warrant the suspicion that the parasites were directly or indirectly responsible for their existence.

In a study of the intestinal flora, at three different periods of the patient's illness, and also at autopsy, none but the usual bacteria common in the intestine could be found, altho a diligent search was made especially for members of the typhoid-dysentery group. Moreover, frequent blood examinations for the agglutination reactions against typhoid, paratyphoid, and the dysentery group, and blood cultures, both antemortem and postmortem, failed to reveal specific agglutinins for these bacteria, or the presence of an organism which might have been responsible for the existing condition.

## BIOLOGY.

The parasite studied by us belongs to the ciliated infusoria; is egg-shaped, and measures from 0.07 to 0.1 mm. in length, by 0.05 to 0.07 mm. in breadth, with a funnel-shaped mouth situated on its ventral portion, a little below the anterior or more pointed pole. The peristome is beset with a thick layer of long cilia; their motion, being in a circular direction, suggests the action of a rotary lawn sprinkler. By these cilia, the organism is able to grasp its food, consisting of various cells and bacteria, from the feces. The

funnel-shaped mouth communicates with the endosarc through a short gullet, this latter structure extending backward and downward.

The endosarc consists of coarse and fine and highly refractile granules, inclosed in a thin and very transparent sheath, continuous from the gullet above and ending at the anus situated at the posterior or more rounded pole. This observation does not conform with Strong's[3] assertion that this granular matter of the endosarc is surrounded by a layer of spirally striated protoplasm. We have been able, by very simple means, to prove this point beyond doubt. One drop of a weak aq. sol. of eosin was placed on the side of an ordinary slide preparation of feces containing Balantidia. The stain, quickly diffusing through the feces, was refused by the organisms which were feeding. In a short while the sheath of the endosarc would be seen to contract from downward upward, carrying before it its contents, until this appeared as a granular spherical body immediately behind its mouth; the lower portion of the sheath, still attached to the anus, remaining as a broad band (Plate 1, Figs. 13 and 14).

A nucleus, usually kidney-shaped, lies in the endosarc below and, usually, to one side of the peristome. It is quite movable, changing its position constantly with the motion of the granular material. Its protoplasm, in the young and adult parasites, stains intensely and homogeneously by ordinary stains; but becomes granular and reticulated when segmentation is about to take place.

Vacuoles in the endosarc have been seldom seen by us in the parasite while feeding, and never while segmenting; but we have repeatedly observed them when the organism was at rest after feeding. Their constant change in number and size, together with a churning motion of the protoplasm and destruction of cells ingested, suggested the probability that their function is concerned with metabolism. When present, they number from one to six in a single parasite. While these vacuoles appear and disappear and fuse with one another and separate again, it cannot be said that they are contractile, for, while they may disappear from the field, by carefully focusing they can be followed through other parts of the endosarc. However, as Stein[16] has pointed out, they are connected by lacunae. In this manner, several smaller ones may form larger

ones, until, at times, the whole lower third of the parasite is taken up by a single large vacuole. We have often seen parts of larger, or entire small vacuoles, expelled through the anus, surrounded by a thin rim of protoplasm (Plate 1, Figs. 6 and 7); these, after a short time, would burst and become lost as granular matter in the surrounding medium.

Inclosing the endosarc, and separated from it by a narrow rim of homogeneous protoplasm (the ectosarc), is a thick cuticle striated longitudinally, the striations extending from the peristome on the ventral surface, and from a point on a level with it on the dorsal surface to the anus at the posterior pole. These striations are undoubtedly muscular structures and, as each is beset with a row of cilia extending throughout its entire length, it is evident that they control the movements of these, as well as the various motions of the parasite.

Cilia are to be found around the peristome, where they are longest, and around the longitudinal striation of the cuticle; there are no cilia between these bands and only a few irregularly scattered ones on the end of the anterior pole above the beginning of the striations.

By the aid of the coarse cilia and muscular bands, the parasite was able to move rapidly through fecal matter, and the comparative ease with which it is capable of moving large particles of matter which happen in its path attests the force of this motion. By contracting these muscular bands, the organism may become perfectly round and quite often uses this means in changing its route. Again, the parasite may become quite elongated or spindle-shaped when it attempts to pass between objects too large to be moved (Plate 1, Figs. 4 and 5).

Pseudopods, formed by protrusions of the endo- and ectosarc, have been encountered in a few instances; they are not limited to any part of the parasite, but may appear to either side, or about the posterior pole. They are more often about the latter site. They may be single, or many may be present simultaneously. We believe them to be a beginning of degeneration, for, after becoming spherical and attached to the mother cell by a thin pedicle, they are cast off as granular masses, and disintegrate.

Gurvich[8] and Strong[3] believe that Balantidia die by discharging the greater part of their granular endosarc through the mouth; the latter author also reports that he has seen this granular material discharged through the anus and through the breaks following the rupture of pseudopods. We have never observed the former phenomenon, but have often witnessed and produced by artificial means (weak solutions of sodium hydroxide or quinine, applied to the edge of the cover glass) the spontaneous rupture and discharge of the granular mass of the endosarc through the latter openings (Plate 1, Fig. 15).

While the influence of the warm stage plays an important part in accelerating their motion and hastening segmentation, we were unable to prolong the lives of the parasites either by incubation or by room or refrigerator temperature; disintegration and death seemed to be due more likely to chemical changes in the feces than to any thermal cause (Plate 1, Figs. 11 and 12).

**Conjugation.**—Wising[9] has described a method of conjugation by which two individuals become united at their peristome, fertilization taking place by the interchange of plasma. Woit[10] and Gurvich,[8] on the other hand, have described what they believe to be conjugation and reproduction, in which two individuals become encysted together with subsequent segmentation into spherules.

We have repeatedly observed a phenomenon in our parasite, which, from its constant occurrence when segmentation is about to take place, suggests itself as the most plausible description of conjugation.

Two adult parasites come together and at once begin to rotate around each other, but in an opposite direction. When their anal extremities meet, their motion slows for an instant and both press down upon the other. Their motion is again accelerated, rotation continues until these parts meet again, and the process is repeated. This continues until segmentation is well advanced. Coarse granular bodies are being constantly discharged from the anal orifices of both individuals during conjugation; these, being pushed aside by the rotary motion of both parasites, form around them a nestlike arrangement in which they remain until segmentation is complete. While we believe that an interchange of these granules may pass

from one parasite to the other during conjugation, we were unable to confirm our belief. We have observed the above phenomena for several hours, with a high dry objective, never having to move the slide to keep the two individuals in the field (Plate 2, Figs. 1, 2, 3).

**Reproduction.**—Many methods of reproduction have been described by various authors; thus, Gurvich[8] believes that he saw segmentation into spherules following conjugation of two individuals in one cyst; others have described the process by budding, the parasite revolves on its axis several times, the cilia stop, and a protrusion of ectosarc occurs. This increases in size, becomes globular, acquires nuclear granules and granular particles from the endosarc of the mother cells, the pedicle connecting it breaks, and the young parasite becomes free. Bushuyeff[11] observed ameboid movements in these segments. Lavrovskaya[12] observed the process of separation from the mother cell; she also observed granular bodies surrounded by a membrane inclosing a nucleus and vacuoles, but failed to find cilia or motion to these bodies. Bushuyeff[11] also observed these forms without motion or cilia, and Zhegaloff[13] saw movement in their granulation. These authors were, however, unable to witness the transition of these protoplasmic bodies into adult parasites. We have often seen such bodies with and without vacuoles, formed from motile as well as resting parasites, having watched their development and their subsequent separation from the parent organism; but we have always seen them disintegrate. They must be regarded as degenerations, as the death of the parasite from which they originated has invariably followed (Plate 1, Figs. 6, 7, 8, 9, 10). Gurvich[8] did not observe budding, but found moving bodies half the size of adult Balantidia which were supplied with cilia. Strong[3] suggests that the bodies described by Gurvich[8] were evidently young parasites. We are able to confirm Strong's[3] statement, as we frequently met such bodies with poorly defined nucleus and peristome, with slowly moving cilia, barely more than one-third the size of an adult Balantidium; the slow motion of these young parasites being the result of recent segmentation (Plate 3, Fig. 1).

We believe that reproduction takes place only by amitotic divi-

sion, as Ekecrantz,[14] Wising,[9] Leuckart,[15] Strong,[3] and others contend. The process, as we have seen it repeatedly, is as follows: After rotation and conjugation, as described above, has continued for some time, the outer cuticle of both parasites becomes lax. As segmentation of one parasite usually precedes by some time that of the other, the cuticle of the one nearest division is the more lax and consequently overlaps that of its mate. Their rotary motion is now sluggish and their nuclei become reticulated and elongated. About this time there appears about the center of the parasite a ciliated girdle which, slowly contracting, shows plainly a constriction, at first shallow, soon becoming deeper, and carrying with it the endosarc. Division of the nucleus takes place, each segment receiving its portion. The two segments are now connected only by a thin pedicle consisting of the outer cuticle and sheath of the endosarc; the pedicle breaks and complete division follows, the band of cilia around the parasite becoming the adoral cilia of the lower segment, while at the point of separation of the upper segment is formed its anus. The cilia movements of the lower stop shortly before complete division takes place, to recur only after the peristome and nucleus are well developed. These young parasites, hardly motile, with an ill-defined peristome and granular nucleus, correspond to those described by Gurvich as transitional forms (Plate 2, Fig. 1).

**Encysted Forms.**—Leuckart[15] and Stein[16] have described encysted Balantidia in which the parasite loses its cilia and becomes rounded, its endosarc contracts and contains fat globules, the nucleus is obscured, and the whole mass is surrounded by a thick capsule. We have observed these, excepting that the nucleus always appeared to us quite distinct, and the outer capsule, while well defined, did not appear thicker than is usually found in the active forms. It is possible that the forms observed were ones not completely encysted (Plate 3, Fig. 2).

**Cultivation.**—Our attempt to cultivate the parasite on Novy-MacNeal's media using human and rabbit blood on acid and alkaline agar, on Musgrave and Clegg's media with different degrees of acidity and alkalinity, in acid and alkaline broth and on water-agar titrated from 1.0 acid to 2.0 alkaline, using the feces and its

bacteria as symbiotics, has met with little success. Results might have been different had not the unexpected termination of our case forbidden further attempt.

**Animal Experiment.**—Wising,[9] Rapshevski,[17] Chigayeff,[18] Lavrovskaya,[12] Zhegaloff,[13] and Strong[3] have injected feces containing Balantidia in cats, dogs, rabbits, pigs, and monkeys with and without previously traumatizing the parts, with negative results. Moreover, Grassi[19] and Calanruccio[20] were unable to infect themselves after injecting Balantidia from the hog. On the other hand, Vlayeff[21] produced lesions in two cats by injecting in the stomach of one and in the rectum of the other feces containing the parasites; and Cassagrandi and Barbagello[22] and Chichulin[7] produced lesions in these animals after colitis had been induced by trauma. These observers, however, failed to find, or to record, the presence of Balantidia at their autopsies on these animals, and no mention is made of the study of symbiotics injected with the feces. It is possible that the catarrhal condition of the bowels found might have been due to the bacteria contained in the feces with the parasites, or to the entrance of bacteria already present in the traumatized gut, rather than to the parasites which were evidently not recovered at autopsy.

From the conflicting results obtained by these observers it was evident that no definite conclusions could be arrived at by repeating their experiments unless artificial cultivation had been successful and the organism obtained in pure culture. As we have failed to accomplish this, we believe that a correct understanding of the rôle played by these parasites can be obtained far better by a careful study of the proper interpretations of the histological findings, than by experiments with an organism which can only be fed or injected to animals in symbiosis with pathogenic or non-pathogenic bacteria.

## SUMMARY AND CONCLUSIONS.

We have repeatedly found Balantidium coli in large numbers in the stools of patients during life; we have found them active and very numerous about the lesions at autopsy. In the intestines of both Dr. Mallory's case and ours, we have found Balantidium coli in sections of the glands of the large intestine and interglandular

supporting tissue, the submucous coat, and in the blood vessels, and, wherever the parasites were present, lymphoid and plasma cells and eosinophiles were constantly in evidence, whereas the absence of such cellular infiltration foretold a negative finding of the parasite.

We believe that ulcerations are due to terminal invading bacteria, as evidenced by their acute character (polymorphonuclear leukocytes, fibrin), and while we do not doubt that Balantidium coli is primarily responsible for their presence by producing avenues for the entrance of these bacteria, the absence of parasites from the walls of these ulcers is sufficient evidence that they play no further part in their production.

From our study of the intestinal flora and the negative blood reactions for specific agglutinins, we are satisfied that any of the bacteria normally present in the intestine of man may produce the ulcerations after Balantidium coli has opened the avenues for infection. We believe that Balantidia produce these definite lesions (hyperplasia and cell infiltration) either mechanically or through the liberation of cytolytic ferments.

The presence of the parasite in blood vessels and lymph spaces leaves no doubt that infection of the liver and lung may occur through these channels in a manner similar to that described by Gage[23] in an invasion of the lungs by Strongyloides intestinalis, or as frequently happens in intestinal amebiasis.

Finally, from the definite and constant microscopic findings and negative blood and cultural results for other intestinal invaders, the logical conclusion seems to be that Balantidium coli is not a harmless commensal, as some authors suppose, but an organism able to invade the human tissues and cause a serious disease; death may follow through compression of the intestinal glands by a hyperplasia of interglandular tissue produced by the parasites and through glandular necrosis and absorption of toxins from any terminal bacterial invasion.

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## EXPLANATION OF PLATES.

### PLATE 1.

FIGS. 1–5.—Active stage of the organism, Fig. 4 representing the form assumed by a parasite when changing its direction, and Fig. 5 when passing between objects too large to be moved.

FIGS. 6–10.—Degenerating stages of the organism. So-called "budding forms."

FIGS. 11, 12.—Appearance of organism after 24 hours' incubation at 37° C., 25° C., and 10° C.

FIGS. 13–16.—Death of organisms following the action upon them of normal sodium hydroxide and 5 per cent quinine sulfate solution, Fig. 16 representing the remaining cuticle after complete discharge of its contents.

### PLATE 2.

FIGS. 1–4.—Conjugation immediately preceding division of the organisms, Fig. 3 representing actual conjugation.

FIGS. 5–9.—Reproduction by amitotic division, following conjugation.

### PLATE 3.

FIG. 1.—Balantidium coli in feces showing a large active parasite and a very small, almost inactive one. ×430 diam.

FIG. 2.—An organism in the resting stage preparatory to becoming encysted. ×430 diam.

FIG. 4.—Small superficial ulcer of the large intestine. Some of the remaining glands of Lieberkühn are atrophied, while others are cystic. ×90 diam.

FIGS. 3, 5, 6.—Balantidium coli in the submucous coat of the large intestine. Figs. 3, 5, ×90 diam. Fig. 6, ×150 diam.

PLATE 4.

FIG. 1.—Balantidium coli in lumen of gland of Luberkuhn. ×250 diam.

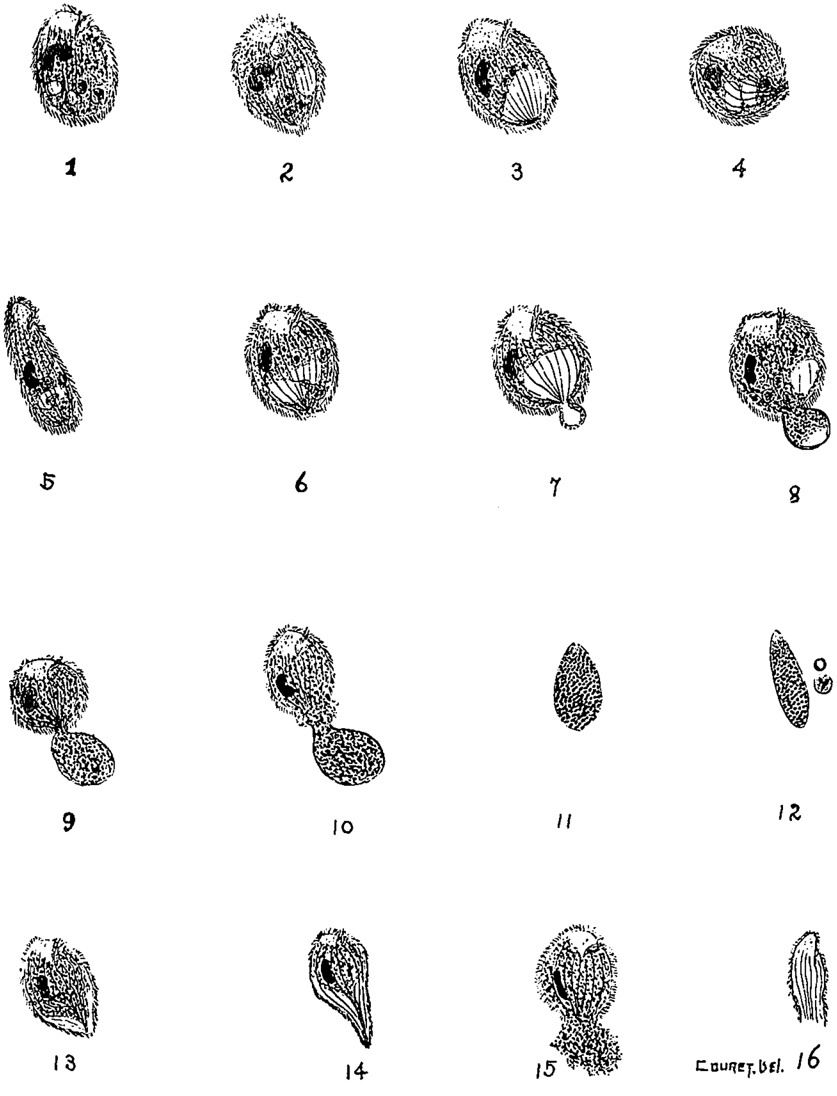
FIGS. 2, 3.—Parasites in interglandular supporting tissue. ×250 diam.

FIG. 4.—Balantidium coli in a small vein. ×250 diam.

FIG. 5.—Parasite in submucous coat. Note infiltration of lymphoid and plasma cells about the organism.

FIG. 6.—The parasite in a lymph space. ×250 diam.

PLATE I.



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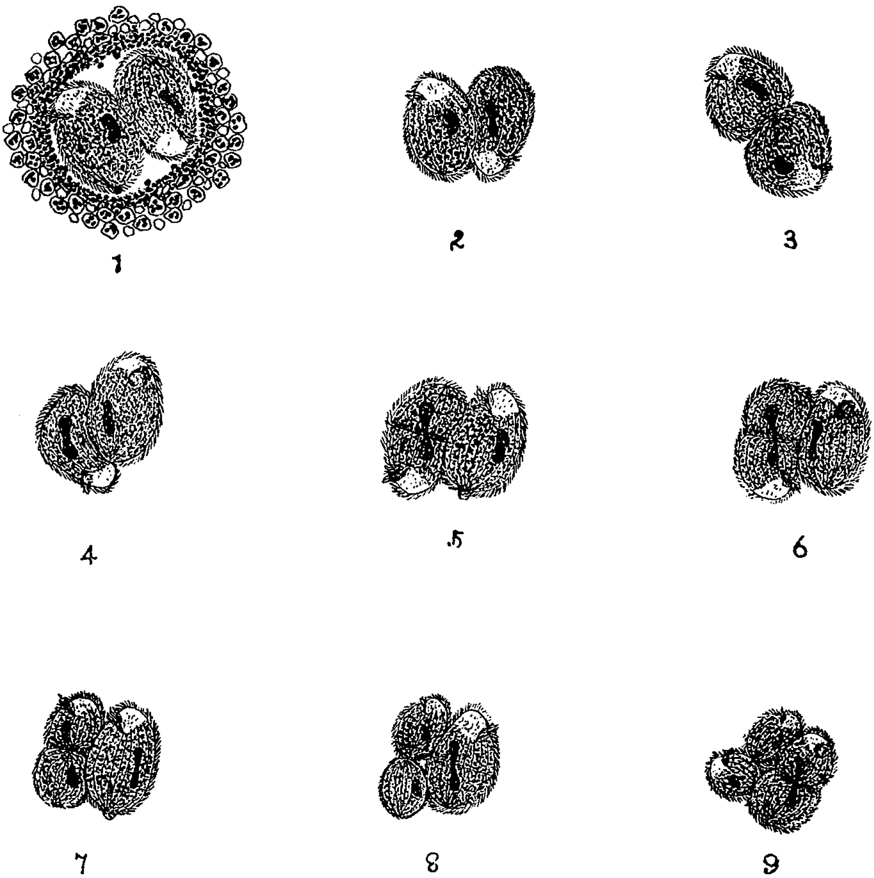


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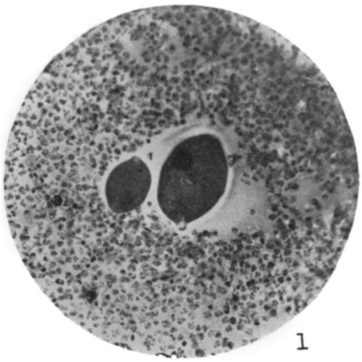
PLATE 3.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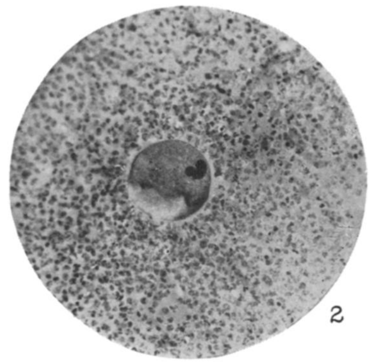
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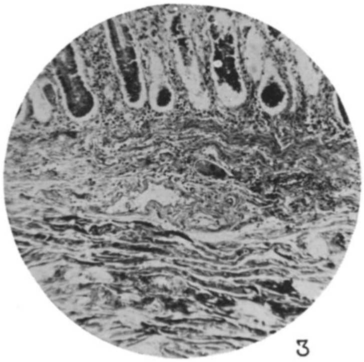
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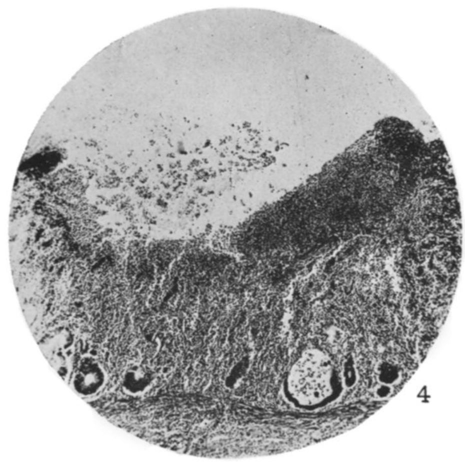
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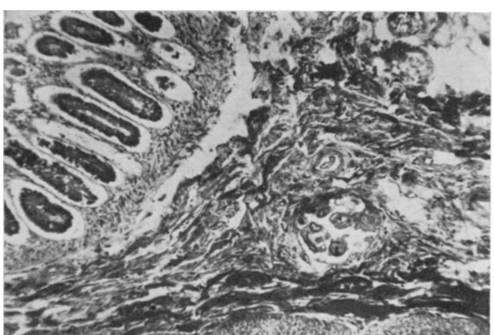
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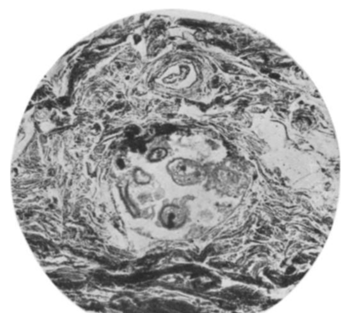

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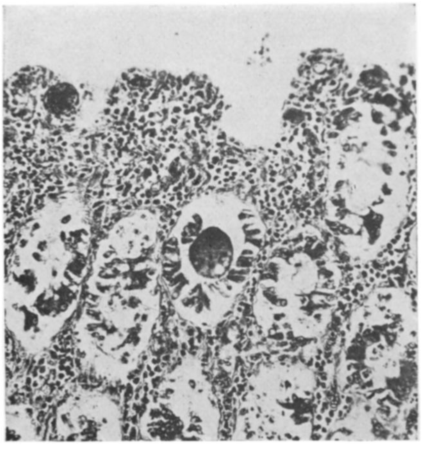

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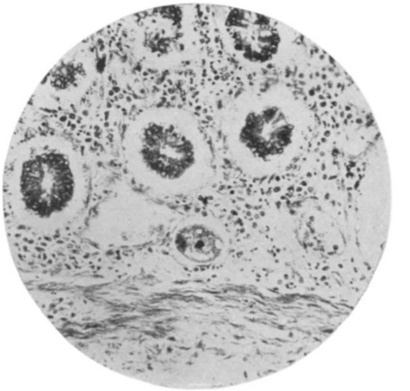

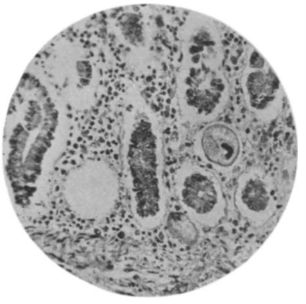

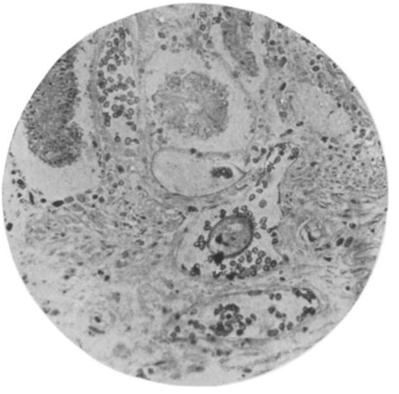

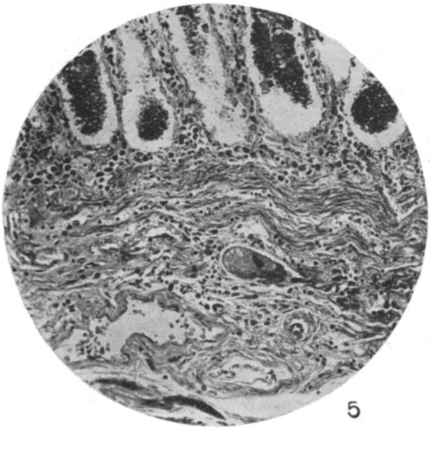

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